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Design of a Telephone And Telegraph Laboratory

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DESIGN OF A TELEPHONE AND TELEGRAPH LABORATORY

BY

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THESIS

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

JOHN FRED McCULLOUGH

ENTITLED DESIGN OF A TELEGRAPH AND TELEPHONE LABORATORY

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Electrical Engineering.

Morgan Brooks

HEAD OF DEPARTMENT OF Electrical Engineering.

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One great difficulty with experimental work is that for a single experiment which does not require more than thirty minutes to perform, it may have required several hours or even days to prepare, especially if it is necessary to construct some special apparatus. For instance if it is desired to make a test on a repeating coil under ordinary working conditions. The conditions under which a repeating coil is used are those of a long distance overhead line of several hundred miles length, on such a line the effects of resistance, capacity, inductance, and leakage are very great and must be considered when instruments or apparatus are tested. If an "artificial line" is constructed so that these different elements; resistance, capacity, and inductance may be readily varied, and if it is placed in a laboratory which is supplied with plugs and spring-jacks the various instruments

may be quickly connected and the whole test made in a very few minutes. The point of facilitating the work should be kept in mind throughout the construction of the laboratory.

Nearly all the factors that enter into the study of telephoning have to be considered also in the study of telegraphy, for instance, on long distance wire the lines have considerable capacity and as the current on these long distance lines is very small and the frequency rather great nearly all of the current can be stored up in the line without any passing through the instrument at the far end, and besides a considerable proportion of the current leaks across from one line to the other without passing through the receiving instrument. Inductance also causes a distortion of the current and prevents waves, but as the frequency of the current waves for telephoning is several

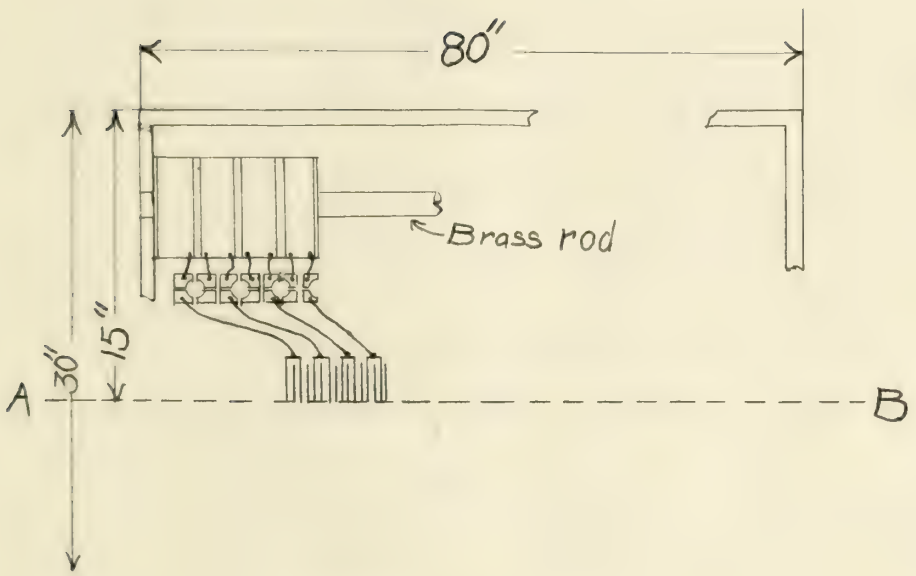
time greater than that of telegraphy waves, a laboratory designed for the study of the distorting effects due to capacity, and inductance on telephone lines, will be ample for the study of telegraphy.

From tests made on an over head line between New York and Chicago Mr. Pupin found that for every ten miles of line there was an inductance of .05 henrys, a capacity of .1 microfarads and a resistance of 10. ohms. If a small coil of .05 henrys inductance be connected to each side of a sending instrument and a similar coil to the other side of the sending instrument, and then a capacity of .1 microfarads be connected across the free ends of the coils, one has an artificial line equivalent to ten miles of over-head line. And if a receiving instrument is connected across the same points as were the condensers, both the receiving and sending instruments will work exactly as they would if they

were on opposite ends of a ten mile overhead line. Of course the imitation of line effects is more nearly correct the smaller the units of inductance and capacity. For this reason the elements of the artificial line constructed for this laboratory should be equivalent to two and one half miles of overhead line. Forty of these coils are to be placed on each rod, and with two rods in each case there will be the equivalent of two parallel wires each one hundred miles long. The rods will have to be of wood or brass as iron or steel rods would act as magnetic cores and would increase the inductance of the coils. It will probably be necessary to construct five such cases of artificial line, giving a total equivalent to a loop of wire one thousand miles long. The coils are to be connected similarly to those of an ordinary resistance box, that is the terminals of the coils will

be soldered to brass bars which have bored holes to accomidate brass plugs which make the circuit continuous. By having several boards with these plugs one one end and plugs on the other end to fit into spring-jacks it will be an easy matter to use as much of the line as wanted or to change from one length to another by simply placing these plugs in different holes.

The drawing of the artificial line on the next sheet is not meant for a working drawing but is merely to show the method of construction and method of connecting coils and condensers.



Sketch of
Artificial Line

A cable of about fifteen pairs with the ordinary lead sheath should be provided so that capacity tests and insulation tests can be made. Besides the fifteen pairs there should be one wire of #8 B+S. guage, with good rubber and braid insulation, running through the center of the cable. This wire is to carry currents of high frequency and high potential, which will be used in connection with Mr. Carty's experiments, to be described later. The cable is to be five hundred feet long and is to be doubled back and forth in such a manner as not to make it inductive. There are to be three openings made in the cable one at the quarter point, half, and three quarter points; at these points the ends are to be fanned out and connected to spring-jacks on marble tablets. In telephone cables each pair of wires are twisted about one another to avoid cross talk between

different pairs; it will be interesting using one wire of the cable for one side of the line and a wire outside of the cable for the return wire to see how much noise there will be when a disturbing current flows through the large central wire, and then to see how nearly the noise is prevented when a twisted pair is used for both sides of the line.

There are to be three small telephone switchboards placed in the laboratory, one to have a capacity of one hundred lines, another fifty lines, and the third to have a capacity of twenty five lines. Connected between each two switchboards there will be ten circuits to be used as trunk lines, the remaining spring jacks will contain circuits running to spring jacks located in different parts of the laboratory, and on the three testing that are to contain the testing instruments. One of these switchboards

should be placed in each of the laboratory rooms and the third one would best be placed in the adjoining lecture room, to be used in demonstrations. It is probable that at first not more than half of the switchboard capacity will be required, but as the increased size adds but little to the expense it is best to allow now for the future requirements of such a laboratory.

The testing tables mentioned above will be three in number and will each be used for tests and experiments of entirely different nature. The first table is to be used for making insulation tests on machines in the electrical laboratory on the first floor, and should have spring jacks for the circuits. There is already a marble tablet in the test room which has several circuits running between it and the switchboards down stairs. Connections can be made from

this Table is the first table, for the current and pressure circuits. A sensitive galvanometer an ammeter and a voltmeter will be required for this table. These ammeters and voltmeters will necessarily have to be constructed to give readings of very minute currents and pressures as only small values of these quantities are dealt with in insulation tests on machines and especially in the ordinary telephone work. This will readily be understood when we consider the statement of a man of authority, who said that from experiments he found that the energy consumed by a sixteen candle-power lamp (fifty watts) was sufficient to produce an audible sound in several million telephone receivers. It is very likely that special ammeters and voltmeters will have to be designed for the work along the line of telephony, a voltmeter for instance having a resistance of several thousand

ohms, could not be used because the moment it was put on the line it would change the line conditions so much, because of the fact that its resistance is not negligible as compared to that of the line. For this reason it is very likely that the voltmeters will have to be of a special electrostatic type.

The second table which will also have spring jacks for ten lines will be used principally for testing the induction coils of telephone instruments, testing especially to find the best ratio of transformation for lines of different lengths. There seems to be a great deal of doubt as to what is the best ratio to use in these coils; it is not very difficult to decide on the best one for a particular line, but the trouble arises in getting the coil that will work the best on all lines. By having two sets of primary coils, each not

consisting of about twelve coils of the same size but of different numbers of turns, and also having two sets of secondaries, of different numbers of turns and made to slip over the primaries, and by having two similar primaries with dissimilar secondaries, connected so that either one may be switched onto the same telephone it will be an easy matter to find which ratio is the best for that particular line. Once by using the artificial line it will be possible to find which ratio works best on all lengths of lines. In order to make these, or any tests where volume of sound is considered, it will be necessary to have the apparatus so arranged that all changes can be made very quickly, for the human ear has to be depended on in all such tests and will carry memory of sound but a short time with any degree of accuracy.

It will also be best, in order to eliminate personal errors as much as possible, to use a graphophone, when comparative tests are to be made on any part of the telephone instruments, especially on transmitters and receivers. The third testing table will contain spring jacks for ten lines also and will be used for general testing.

Probably the most interesting of all the experiments will be those to prove Mr. Carty's statement that telephone cross talk is due to electro static effects and not to electro magnetic currents. It is evident that if current flows in a loop of wire due to magnetic induction the current circulates and is equal at all points of the line, and if several receivers are put in the circuit they will all be equally noisy as the same current flows through them all. But if we consider that cross talk is caused

by electrostatic effects, assuming the disturbing wire at one instant to contain a positive charge it will attract a negative charge in the side of the loop closest, and the free positive charge will flow to the distant side, then one half cycle later the disturbing wire will be negative and the closest wire positive with the farthest one negative. It is evident now that there has been a flow of negative electricity from the closer to the farther wire. As this current divides at the center, of each line flowing in each direction and increasing in quantity the farther it gets from the central points, it can plainly be seen that there will be no flow at the central point of each wire while the flow will be the greatest at the ends of the loop. By placing four receivers in a telephone line at the above mentioned points Mr. Canty proved

his statement as the end phones were very noisy, while the two at the center of the lines were quiet. This experiment can best be represented by using one wire in the cable for one side of the line and then using the trunklines between the three switch boards for the other side, running around often enough to give the proper length to the return wire. By making suitable transpositions this charging and discharging current will nearly all flow across the transpositions leaving the two end phones practically quiet. In telephone cables each pair of wires are twisted about themselves and each half twist corresponds to one transposition. If a receiver is connected at each end of a twisted pair there should both be noiseless, when a disturbing current is flowing through the neutral wire, because of the frequent transpositions. This disturbing wire will be connected

to the power switch boards in the electrical laboratory through the tablet mentioned before and which is located in the east one of the two rooms. By using different dynamos and different speeds the pressure and frequency of the disturbing wave can be varied through a wide range.

The requirements for the work in telegraphy will be a battery of about twenty gravity cells and two sets of ordinary house telegraph instruments with an intermediate repeating set. Each set is to be for single telegraphy and should contain one key, one relay and one sounder, also a local battery of two or three cells. Two sets of instruments for quadruplex telegraphy should be installed; these instruments can be used to represent duplex instruments as well.

With an expenditure of from

$500.00 to $800.00 this Telephone and Telegraph Laboratory could be equipped with a fairly complete lot of apparatus, and many manufacturers would be willing to loan instruments to be studied and experimented with.